DOCUMENT RESUME

ED 172 459 EA 011 904

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TITLE A Model of the Dynamics of Bargaining with a Case Study in Education.
PUB DATE 6 Jun 79
NOTE 20p.; Paper presented at C.S.S.E. Conference (Saskatoon, Saskatchewan, June 1979)

EDRS PRICE MF01/PC01 Plus Postage.
DESCRIPTORS Case Studies; *Collective Bargaining; Elementary Secondary Education; *Mathematical Models

ABSTRACT

This document describes and discusses a mathematical model of the dynamics of bargaining. The model was designed to show the development of the bargaining process and to provide a means by which a prediction may be made with respect to settlement or stalemate. Allowing for multiple goals of the bargaining parties and changing weightings of those goals permit the model to portray the dynamics of bargaining better than more complex models that depend on rational development of single-goal packages. A test of the model in an actual bargaining situation indicated its potential utility. By requiring comparative weightings of the issues under negotiation, use of the model encourages a less intuitive process than is typically the case. The outcome of each round of negotiations is reduced to a set of figures that can be valuable to a mediator, should one be called in. Following sufficient testing of the model, it may be possible to draw a theory of bargaining dynamics from the information gathered. (Author/PGD)

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A MODEL OF THE DYNAMICS OF BARGAINING

WITH A CASE STUDY IN EDUCATION

A Paper

presented

at

C.S.S.E. Conference

Saskatoon

6 June 1979

by

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ON A DYNAMICS OF BARGAINING

Twenty-five years of bargaining experience in a variety of capacities and a deep concern over the directions that labour/management problems appeared to be moving in Education - this direction being assured in Ontario by the passing of Bill 100 in 1975 - led me to an examination of the problem with a view to developing a mathematical model of the bargaining process that would:

(a) show the development of the bargaining process from round to round;

(b) provide a means by which a prediction (however valid) may be made with respect to settlement or stalemate.

Let me hasten to emphasize that it is a model, not a theory, although all the elements to enable theory development are present.

What follows will be a brief listing of the fundamental questions raised, the viewpoint taken by me in addressing the questions, the results of so doing, a case study in which the model was put to use, and some comments with respect to extensibility of the work.

Questions To Be Examined

The following are the issues that were addressed in the creation of the model.

Perhaps it is too obvious to mention that the issue of "bargaining" itself had to be clarified. What types of bargaining have been and are to be considered? Where does bargaining per se rest within the entire area of Conflict Resolution? In short, what definition is to be used?

Since the intent is to describe the dynamics of bargaining the whole concept of dynamics must be addressed. Should one follow the classical models of physics and consider the dynamics - with a small d - as some special form of Dynamics - with a large D? If not, what is meant by dynamics in this context?

The second objective of the study was to obtain some means of predicting the state of the process. Would a settlement be attainable? If so, after how many rounds of negotiation might it be attained? The "might" of course implies some probabilistic measure.

Considering these to be the primary areas of concern, they inevitably must point to a number of secondary questions that are equally pressing when one gets down to the practical problems of model development. Among these are included such topics as optimization, utility, rationality and possibly anticipation. It is, perhaps, useful to include all of these under the rubric of "Concession Making". They are inseparable, therefore, the order in which they are mentioned here implies nothing in terms of relative importance or a causal relationship.

Such questions as the following arise:

(1) Do people try to optimize when negotiating?

(2) If so, what form is the function that is optimized?

(3) If so, is it a scalar valued utility function that is considered?

(4) Are negotiators rational when they negotiate? (Rational being used in the sense of maximizing some function.)

(5) Does concession making include such considerations as anticipation and risk?

Finally, and in a much more fundamental sense, is it realistic to consider bargaining in a two party single goal scenario or might it and should it be cast in a multi-goal multi-party framework?

Viewpoint

Let me return to each of the above and address them briefly with respect to the point of view adopted in this work.

By bargaining I mean the collectivity of actions and reactions by means of which various groups mutually revise their expressed desires, and the alternative paths to their ends. It is, therefore, a process of making concessions. The only restriction, if it might be considered such, is that I assume the negotiations to be carried on in an environment that can be described as one of "perpetual existence", i.e., each party is aware that all parties have a common end of mutual continued existence, and the matters to be settled are perceived to contribute to this end. In a sense it is conceived like a non-zero sum n-player game.

As far as types of bargaining are concerned, it was intended to include all bargaining without an attempt to classify the types as in Walton-McKersie (1965) with the exception that I have explicitly stated the exclusion of "attitudinal structuring" which I feel is the domain of the Psychologist. I now feel the model may be used as a tool to assist in a study of such, but more on that later.

The question with respect to dynamics depends on how one considers the bargaining process. I have used "dynamics" to mean movement of

offers and counter-offers from round-to-round. The formal way in which this is structured depends on the way in which one considers the concession-making activity to come about. More on this in a moment.

Let me address the question of predictability first. Many earlier models claimed the ability to predict a solution to bargaining problems. (Bishop, A. L. 1964; Cross, J. C., 1965; Edgeworth, 1881; Harsanyi, J. C., 1950; Nash, J. F., 1950; Pen, J., 1952.) The earliest were actually indeterminate in the sense that they could only provide a range in which the solution would fall. As the models increased in complexity predictability improved but only through requiring complete information in the game theoretic sense or by placing severe restrictions on the model and thus creating an unattractive distortion of reality. Thus, the viewpoint adopted was that predictability would be in terms of probabilities in the sense that the state of bargaining, say $\underline{y}$ is predictable from some set of conditions or given state say $\underline{x}$ if some estimate of the probabilities of the various values of $\underline{y}$ can be furnished. These probabilities will explicitly depend on the parameters describing the bargaining behaviour and are considered as frequencies, not as idealistic probabilities.

Concession making is at the heart of bargaining. I suggested a number of issues with regards to concession making. Let me address them as a group rather than serially.

If, during the adjustment of one's bids optimization is attempted, what is being optimized? If optimization is to be modelled, do we need some form of smooth continuous function which may be called a utility, such as in the Keeney/Raiffa (1976), work? This obviously would permit one to define rationality as the act of optimizing one's utility

or preferences.

In the past, this line of thinking led to rather complex models and almost always to the need to deal with, ultimately, a single goal structure. It also led to precisely predictable solutions such as that of Nash (1952). But by so doing, it ruled out the very essense of the problems of dynamics; the interchange, the period by period development of the negotiations.

Therefore, I took the viewpoint that the offers and counter-offers were discrete, and the path through time discontinuous and not necessarily developed rationally as defined above. This is not to imply that optimization may not take place during offer adjustments, it merely says that it is not imposed as a requirement in the model. To take this approach permitted the replacement of the utility function by a vector of weights that were permitted to be altered from round to round. It is precisely such output, that is, the changing vectors of weights, that provides the description of the temporal path of the bargaining process, i.e., the portrayal of the dynamics.

Not only did this permit the portrayal of the dynamics but it permitted the inclusion of both multi-parties and multi-goals. A vast simplification but, I believe, a vast increase in applicability!

It was then possible to express the state of bargaining in terms of the number of goals that were "acceptable" to each party where acceptable is defined as having a weight falling within some previously defined interval.

An appropriately structured model would provide the prediction desired.

The model resulting from these considerations is based on the following basic assumptions:

1. Goals can be expressed numerically as weights which may include the degrees of importance of the goals and the degree to which an action or set of actions can satisfy the goals.

2. Concession making is a discontinuous transformation of these weights.

3. The transformations are a result of certain parameters that are behavioural in nature and based on two basic comparisons:

   a) between one's own current bid and his own desired settlement position;

   b) between each opponent's pre-bargaining position and current bid.

The adjustment process is captured in the following equation:

$$w_j^i(t+1) = w_j^i(t) + \mu_j^i(w_j^i(t) - w_j^{i*}) + \phi_j^k(w_j^k(t) - w_j^k(0))$$

where $i = 1, 2, \ldots, m$; $j = 1, 2, \ldots, n$; $k = 1, 2, \ldots, m-1$, and $i \neq k$.

The results of the model in terms of the state of bargaining as previously defined were examined for haphazardness. When dependency was established the nature of the dependency was examined and found to be, in the main, of lag 1. On the basis of this initial examination the assumption was made that the model was Markovian in nature. This assumption was tested by using the model as a simulator and developing a number of scenarios the results of which were used to provide the basis of Markovian predictions. The predicted results were then compared to the observed results, i.e., in the simulations, and were found not to be distinguishable.

This, of course, provides a powerful tool for prediction of settlement or, indeed, of any state of bargaining.

The model was also tested for sensitivity to the initial condition and parameter levels and found to be sensitive to both and to various combinations of both.

The Case Study

The Scenario

There still remains the overriding question of the practical usefulness of the model. To this end permission was sought and granted in late November 1977 to monitor the bargaining process between a Board of Education and one group of teachers in its employ. The following constraints were placed on the monitoring process:

1. Complete confidentiality must be maintained by the researcher.
2. The researcher must not become involved in any way without the mutual consent of both parties.
3. Data gained and information developed by the researcher would be made available to a mediator or arbitrator (in the event that such were assigned) only on the mutual consent of both parties.[1]

By the time permission had been granted, negotiations had been under way for some months.[2] Initially, fourteen items had been under negotiation.

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[1] It is fair to say that both the local teachers' federation group and the Board of Education were willing to cooperate in a test of the model but were cautious with respect to the meaningfulness of the results, if any!

[2] The fact that the model could be applied at this point during the bargaining process indicates that it is independent of time.

Eleven had been agreed upon early in the process. By late November three remained to be settled, namely, salary (G_1), retirement gratuity (G_2), pupil-teacher ratio (G_3). As it turned out the differences with respect to these three goals proved to be too great to be resolved without assistance.

It can be seen that the scenario described above provided a two party three goal situation which was precisely that which was examined by the researcher for the purpose of analyzing the model.

The Initial Conditions

It must be recalled that certain data are necessary to drive the model. These data include three sets of goal weights, namely, the pre-bargaining weights ($W^i(o)$), the target settlement weights (W^i*), and the opening bids ($W^i(1)$), $i = 1, 2$. Upper and lower bounds must also be established around the $W^i(o)$ and W^i*. The totality of these weights and bounds is known as the initial conditions. It is only in the ideal situation that these data are available explicitly. Thus the real problem becomes one of obtaining these initial conditions.

Once permission was granted the researcher spent considerable time with each party, separately, explaining the model and securing its cooperation in developing the concept of measurement of goal weights.[3] Each party was aware of its position on each of the three sets of weights as they traditionally measured them (i.e., dollars for salary, ratio for pupil/teacher ratio and dollars for retirement gratuity). But neither party

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[3] This was done with the aid of interactive computerized version of the model which permitted the parties to simulate a number of rounds of bargaining.

was accustomed to thinking of them in terms of a common weight. The teachers' group found less difficulty with the concept and was relatively quickly able to develop a variety of possible weight vectors. The Board of Education bargaining team, composed mainly of farmers and small businessmen, was able to cope with the concept (understood as percentages) and finally developed the appropriate vectors.

No difficulty was encountered in explaining to either group the notions of the upper and lower bounds.

INITIAL CONDITIONS

		Teachers	Board
Pre-Bargaining ($W^i(o)$)	G_1	.30	.47
	G_2	.38	.25
	G_3	.32	.28
Base Settlement (W^i*)	G_1	.25	.55
	G_2	.28	.20
	G_3	.37	.25
Opening Bid ($W^i(1)$)	G_1	.30	.63
	G_2	.17	.15
	G_3	.53	.22

INITIAL CONDITIONS - cont'd.

			Teachers	Board
Alpha	α	G_1	.04	.02
(Own Upper Bound)		G_2	.04	.02
		G_3	.04	.02
Beta	β	G_1	0	0
(Own Lower Bound)		G_2	0	0
		G_3	0	0
Delta	δ	G_1	0	0
(Opponent's Upper Bound)		G_2	0	0
		G_3	0	0
Gamma	γ	G_1	.02	.03
(Opponent's Lower Bound)		G_2	.02	.03
		G_3	.02	.03

TABLE 1.1

The initial conditions, as shown above, illustrate the basic differences in the positions taken by the two parties as well as their intransigence with rspect to their own requests and their attitude towards the opponent.[4] The teachers indicated $W^1(o)$ as approximately equal across the three goals

[4] Intransigence may be due to ideological differences in which case the α and β collapse to zero.

in question, whereas the trustees considered the weightings to be close to 2:1:1 in proportion. The W^{1}* reflected the fact that the teachers hoped to maintain the 1:1:1 proportion with minor shifts from the retirement gratuity in favour of both salary and pupil/teacher ratio. The trustees, on the other hand, wished to place less emphasis on the retirement gratuity and much more on salary with only a minor shift on pupil/teacher ratio.

The previous experience in negotiating over other items, now settled, had led the teachers to hold more or less well-defined positions - now the opening bids $W^{1}(1)$ - that could be considered extreme in at least one area, namely, that of the pupil/teacher ratio (G_3). All others, although outside the tolerance bound, could be considered to be within the realm of negotiability.

The Reaction Parameters

The concepts of making adjustments in the bids was intuitively clear to and readily accepted by both groups. Likewise, the behavioral assumption - that each party consider the positions taken by the other parties in the immediately preceeding round - was no surprise to either party. However, an outright and explicit identification of the numerical values of the reaction parameters appeared to be infeasible. Nevertheless, the nature of reaction could be easily identified in terms of four levels, namely, 'high' (2), 'medium' (3), 'low' (4) and 'null' (1) through discussion with members of the negotiating teams, many of whom had two or more years of experience in bargaining in that jurisdiction.[5]

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[5] The mean number of years of experience in that system was 4.2 for the teachers and 4.7 for the trustees.

In the past, relations between the two groups had been amicable. Both groups identified the same parameter level combination as the most appropriate description of the adjustment process in previous years. This was a 'medium' level self-adjustment parameter (μ) and a 'null' level opponent adjustment parameter (μ). It appeared though that the relationship had altered over the past few months and each side identified the 'high' level as the most likely for both reaction parameters (ϕ and μ) for the immediate future negotiations.[6]

The choice of the actual values of μ and ϕ was that of the analyst. These values, obviously subjective in nature, were used for simulation. That is, various perturbations were made resulting in a variety of submissions.

The Monitoring Process

The negotiations were monitored by the analyst with a view to relating the numerical value of the bids to goal weights as used in the model.[7]

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6 The past negotiations could be characterized as 3,1 for μ and ϕ respectively, whereas the most likely characterization for the immediate future would be 2,2. In terms of the simulations mentioned above, 331 would represent the past, whereas 322 would likely represent the future.

7 The weights were established subjectively by the chief negotiator for each team in discussion with the analyst as quickly as possible following the negotiating rounds. In most instances this was the following day for at least one party. It must be emphasized that these were entirely subjective.

The data in Table 1.1 were used as the basis for a number of simulations, each of 100 rounds. The perturbations of the reaction parameters mentioned above gave rise to the different simulations and provided a data base for comparison of the $W^1(t)$ as obtained by observation on the part of the analyst and the parties.

The observed data was compared with the simulation results. The simulation results that appeared to be the closest approximation to the observed data are shown in Table 1.2. The observed data are shown in Table 1.3. The data in Table 1.3 terminate at round 21 as it was at this point that a mediator was appointed.

A t-test for paired data was performed to test the hypothesis that there was no difference in the two series at the 95% level of significance. The nypothesis was upheld as the t-statistic was .56 which falls within ± 2.086 for 20 degrees of freedom.

The simulation results show a roughly cyclic pattern beginning at round 18. Had they known this, and accepted it, the parties could have either altered their approach to the negotiations or opted for a mediator early in the process. According to the initial agreement, no such information was given to either side.[8]

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[8] It is interesting to note that a stalemate was recognized at the end of round 21, after six weeks of negotiations, and after a lengthy period of time both parties agreed to accept a mediator. They also gave permission, after examining the data, to provide them to the mediator.

NUMBER OF GOALS WITHIN BOUNDS AT THE END OF EACH ROUND

(Simulation Results)

Round									
1	2	3	4	5	6	7	8	9	10
3	0	0	1	1	1	0	1	0	2
1	2	1	1	1	1	1	2	1	1
1	2	1	1	1	2	1	1	1	2
1	1	1	2	1	1	1	2	1	1
1	2	1	1	1	2	1	1	1	2
1	1	1	2	1	1	1	2	1	1
1	2	1	1	1	2	1	1	1	2
1	1	1	2	1	1	1	2	1	1
1	1	1	2	1	1	1	2	1	1

TABLE 1.2

NUMBER OF GOALS WITHIN BOUNDS AT THE END OF EACH ROUND

(Observed Data)

Round									
1	2	3	4	5	6	7	8	9	10
3	0	1	1	1	1	0	1	0	2
0	2	0	1	0	1	0	2	0	1

TABLE 1.3

Upon examining the data in Table 1.3 it appears as though the parties were on the verge of settlement at round 1. In actual fact, they were not because although three goals were within bounds there was no goal for which the parties were simultaneously within the bounds of acceptability. At the end of round 10, both parties were within bounds on the same goals, one of the parties, the teachers, refused to settle on that goal until the others were also settled.

The mediator selected this point (i.e., the end of round 10) as his opening position. The $W^i(10)$ vectors were

Teachers (.44, .28, .28)

Board (.62, .22, .16)

The impasse was resolved within five hours of mediated negotiations with the settlement vector being:

Teachers (.37, .28, .35)

Board (.55, .22, .23)

It is evident that the model, at least in the mentioned context, was able to provide a fairly accurate description of the process. The two parties and the mediator felt that the exercise had been fruitful in that it served to focus attention on the specific goals and their inter-relationships. The mediator was cautiously enthusiastic; the use of the model was perceived by him to produce a clear picture of the results of the previous rounds of negotiation and to provide him with a point from which he could begin his task.

Comments on Future Developments

The empirical testing of the model as reported in the case study points out the possible use in the real world. The mediator was cautiously enthusiastic. The problems encountered in making the application centered around the concept of goal weights. Both parties were used to using the measure of dollars or pupil-teacher ratio. It was difficult to move away from this. It was done by interpreting all three goals into dollars and then entering into a discussion as to the relative importance of the issues

distinct from dollars. In short the difficulty in application arises in gaining the inputs.

I have made one further application, again with a group of teachers. This time I was simply acting as a consultant to the one group, but I have been able to provide a number of simulations, on the assumption that the board would continue to act as in the past. This has provided the group with an interesting insight into their behaviour which can best be described as "Hat in Hand".

I have also created a classroom game version of the model which I have used over 12 rounds with a group of graduate students, 60% of whom have had bargaining experience in education. Apart from the motivational aspects of the game, it has provided me with some insights into bargaining behaviour.

Future development should be directed as follows:

(a) A larger number of simulations should be developed to provide a much broader data base for comparative purposes in future application.

(b) A particular application is presently being attempted in the area of multicultural interactions. There is a small group of professors in our Faculty with a breadth of experience in this area. One has taken part in the aforementioned game, and is now exploring the applicability of it to the field of multicultural interactions.

(c) The interactive game form of the model, where the object is to arrive at the parameter values, i.e., μ and ϕ and thus control the bid adjustments, can be used as a tool in a controlled laboratory situation to gather information on bargaining behaviour. In the one application of this type to date each player was required to, independently, keep a structured log of his decision making. These are now being examined by myself and a psychologist colleague with the view to improving the log structure and eventually being directed toward some hypothesis with respect to a theory of bargaining behaviour.

I feel there may well be a way of further developing the model itself to provide some way of predicting possible changes in the parameters μ and ϕ due to previous patterns of their values. This may grow out of the examination of the logs. As yet no attempt has been made to do such.

The two objectives have been met, both theoretically and practically. More work is possible that may well lead to a theory of bargaining behaviour.

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